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Structures and deformation phases affecting the Diagorou-Darbani greenstone belt south of Téra (Liptako, West Niger, and West African Craton)

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Abstract

The present study focuses on the geological formations of the Diagorou-Darbani greenstone belt of southern Téra in the Niger Liptako (NE portion of the Man Shield of the West African Craton). The main objective of this study is to characterize the deformation phases that affected the Diagorou-Darbani greenstone belt to the south of Téra. The methodology implemented is based on a structural analysis using field data. These formations are affected by two major deformation phases, D1 and D2. Phase D1 comprises three episodes: D1a, D1b and D1c. The first episode (D1a) developed the S1 cleavage (NE-SW). This episode is linked to a NW-SE shortening (N130°). The second episode (D1b) is marked by S2 crenulation cleavage, micro-folding and the dextral reactivation of N45° shear zones. This episode is linked to an E-W shortening. The third episode (D1c) is highlighted by the NW-SE S3 fracture cleavage and the sinistral reactivation of the N45° shear zones. A N-S to NNE-SSW shortening was obtained for episode D1c. Phase D2 is essentially brittle. It favoured the development of submeridian fractures and conjugate WNW-ESE (sinistral) and ENE-WSW (dextral) shear fractures. This deformation is compatible with a generally E-W direction of shortening.

Keywords: West African Craton; Deformation; Diagorou-Darbani; Liptako; Niger

1. Introduction

The Birimian formations, oriented broadly NE-SW, were deformed by the Eburnean polyphase thermo-tectonic event [1] between 2.16 and 1.98 Ga [2]–[8]. This event is divided into 2 to 4 major deformation phases, noted respectively: D1, D2, D3 and D4. These deformation phases generated several structural elements [9]–[14]. The first three phases (D1 to D3) are regional in character, unlike D4, which has only been recognised locally, particularly in the Liptako region of Niger [15], [16]. Phase D1 is the subject of debate. For some authors, it is associated with modern tangential collisional tectonics [2], [3], [5], [13], and for others, it is a question of vertical, archaic tectonics of the Archean type [9]–[11], [17], [18]. The deformation phases D2, D3 and D4 have been linked by some authors to the functioning of the major shear zones [2], [3], [12], [16], [19], [20].

Very little structural data has been published for the Niger Liptako. Structural studies carried out in the Liptako have mainly focused on the Sirba [21], Diagorou-Darbani [11], [16], Gorouol [22] and Makalondi [23] greenstone belts. Structural studies undertaken mainly in granitoid plutons are few and have concerned the Téra-Ayorou pluton [9], [17], [24], [25]. The aim of this study is to characterize the various deformation phases that affected the Birimian formations in the Diagorou-Darbani greenstone belt to the south of Téra and to determine the average directions of shortening.

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2. Geological context

The West African Craton consists of two Shield, the Reguibat Shield in the north and the Léo-Man Shield in the south, each comprising an Archean western province dated at 3.5 to 2.7 Ga [26], [27] and a Birimian eastern province dated at 2.27 to 1.96 Ga [20]. The Niger Liptako corresponds to the north-eastern (NE) edge of the Léo-Man Shield (Figure 1a). The Niger Liptako is characterized by alternating greenstone belts (Gorouol, Diagorou-Darbani, Sirba and Makalondi) and granitoid plutons (Téra-Ayorou, Dargol-Gothèye and Torodi) trending broadly NE-SW (Figure 1a). The greenstone belts consist of metabasalts with local pillow lavas, amphibolites, ultramafic to mafic plutonites often transformed into talcchists, talc-chloritoschists and chloritoschists, metamorphosed sediments and volcano-sediments, ranging from greenschist to amphibolite facies [16], [21]–[23], [28]–[39]. These belt rocks are intruded by granitic to dioritic plutons, sometimes associated with intermediate to acid volcanics [22], [29]. The granitoid plutons have an elongation direction sub-parallel to the major N45°E shear zones [11]. They are represented by granodiorites, tonalites and quartz diorites, locally gneissified at the contact with the host rock [9], [16], [17]. The U-Pb ages on zircon obtained from the plutons range from 2174 ± 4 Ma (Dargol pluton, [16]) to 2158 ± 9 Ma (Téra pluton, [40]). The Diagorou-Darbani greenstone belt studied here is located in the central part of the Niger Liptako. It is divided into two branches with a mean strike N45°E, separated by the Taka pluton (Figure 1b). The western branch is predominantly magmatic, while the eastern branch is sedimentary and volcano-sedimentary (Figure 1b).

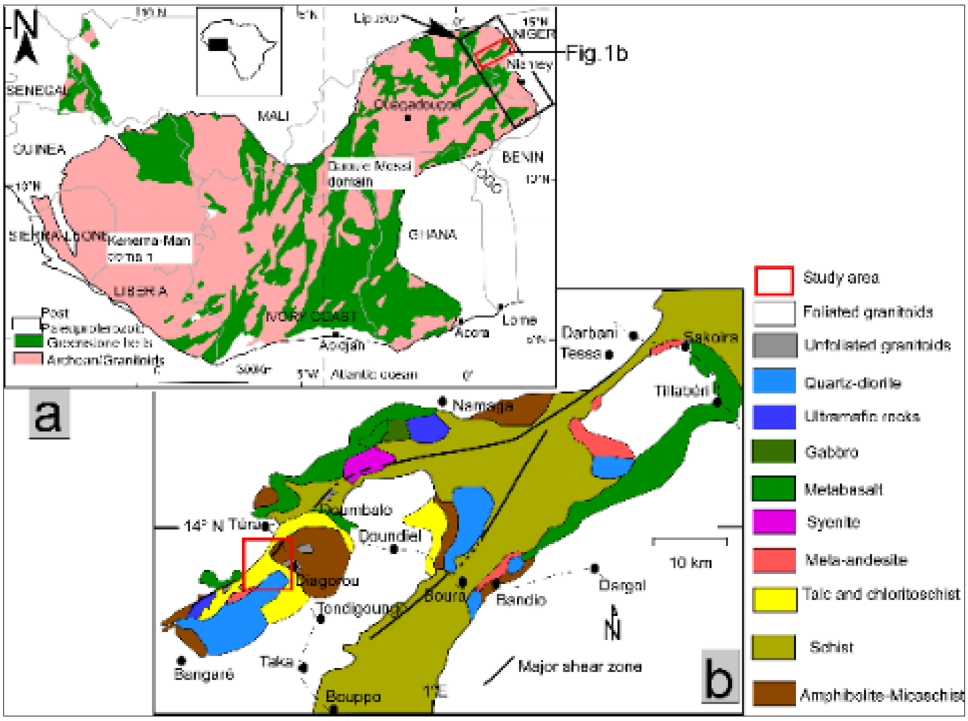

Figure 1 (a) Synthetic geological map of the Man Ridge modified from [41]; (b) Geological map of the Diagorou-Darbani Birim belt modified from [31].

3. Methodology

The methodology used for this study consisted of field and laboratory work. The field work consisted of surveys, petrographic description, structural measurements and sampling. The methodology used consisted of a structural analysis of the surrounding rocks in the field. This structural analysis involved identifying and describing the geological structures affecting the host rocks and pegmatites.

In the case of the host rocks, this involved structural measurements of foliation/cleavage, the presence of lineation, faults, shear or folding zones. In the laboratory, the various structural measurements collected in the field were automatically projected onto the SCHMIDT diagram (lower hemisphere) using the program (Stereonet 9, [42]). The resulting stereograms allow us to deduce the different average directions of shortening responsible for the different structures observed in the field. The laboratory work involved making thin sections and observing them under a polarizing microscope, with a view to characterizing the tectonic microstructures. The study of cross-relationships between tectonic structures identified in outcrop and during microtectonic studies.

4. Results

The Diagorou-Darbani greenstone belt has two deformation phases, D1 and D2. The first deformation phase, D1, is characterized by cleavage, micro-folding, boudinage and shear zones. This D1 phase comprises three episodes D1a (ductile to semi-ductile), D1b (semi-ductile) and D1c (semi-ductile to brittle). The second deformation phase D2, is brittle and post-Birimian.

4.1. Deformation phase D1

4.1.1. Episode D1a

The ductile to semi-ductile deformation episode is characterized by symmetrical cleavage/foliation (S1) running N35° to N55° (Figure 2a). This cleavage affects talcchists, micaschists and quartzites. The stereograms show an average shortening of N130° (Figure 2b).

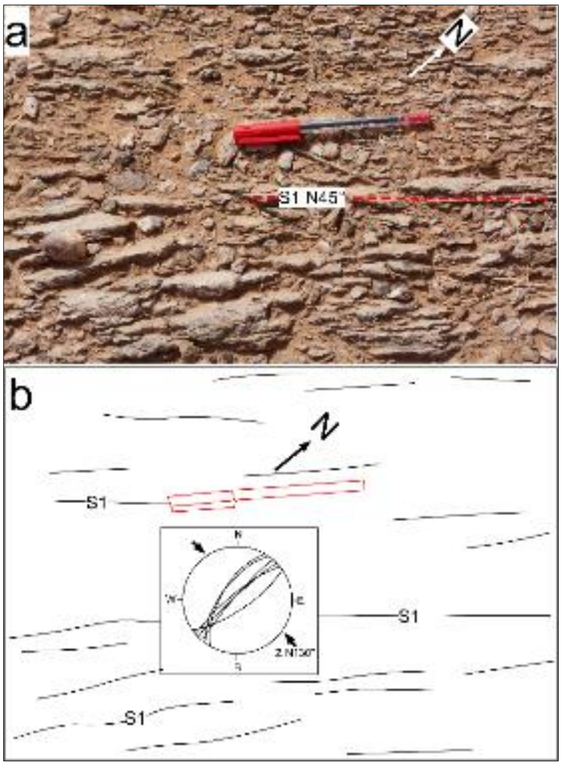

Figure 2 (a) S1 foliation with orientation N25° to N45° observed in the talcschist; (b) S1 foliation, with stereogram showing the direction of shortening (N130°) of S1

4.1.2. Episode D1b

The D1a episode of ductile to semi-ductile deformation is followed by a second semi-ductile episode D1b. The D1b deformation is characterized by cleavage/foliation S2 in the axial plane direction N40° to N70°, microfolding, boudinage and dextral shear zones.

4.1.2.1. Microfolding

The cleavage/ foliation (S1) is often affected by an episode of P2 microfolding. Anisopach P2 microfolds with axes oriented N35° to N45° are generally observed in talcchists. The axes of these microfolds dip 10° to 30° to the NE. Exaggerated folding can sometimes lead to the development of axial plane or crenulation cleavage (S2), sub-parallel to the axial planes of the P2 microfolds (Figures 3a and b). The S2 cleavage trends between N40º and Nº45 with dips varying from 65º to 85^{0}, generally to the NW.

4.1.2.2. Dextral shear zones

The N45° to N70° dextral shear zones affecting the talcschist are responsible for the development of the S1/C mills. A shortening N70° to E-W has been obtained for these dextral shear zones (Figures 3c and d).

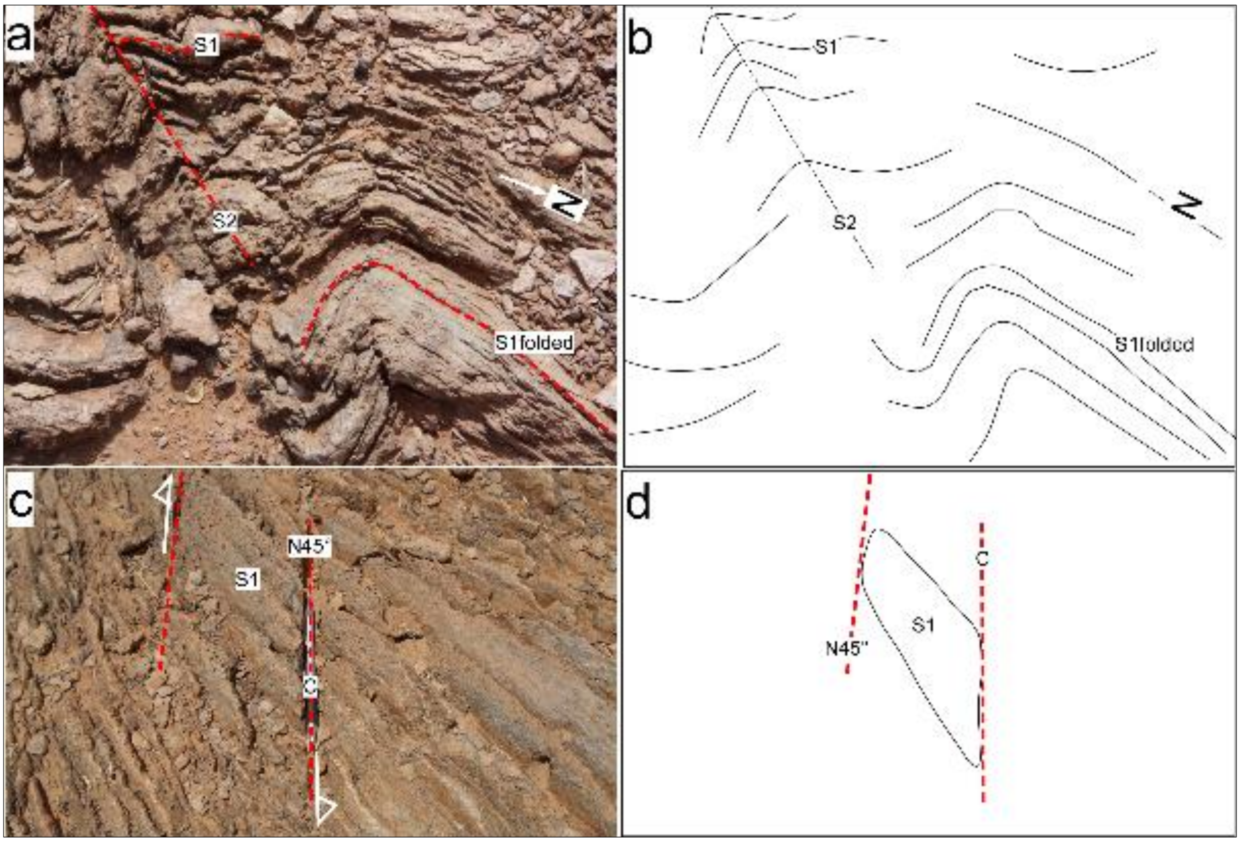

Figure 3 (a, b) Microfolding of S1 inducing a subparallel crenulation S2 cleavage in the axial planes of the microfolds; (c, d) S/C fabric with a dextral shearing component affecting the talcschist

4.1.3. Episode D1c

The semi-ductile to brittle D1c episode is associated with a cleavage of S3 fractures oriented N90° to N140° and S1/C fabrications, associated with the play of sinistral shear zones (Figure 4). A N20° shortening was obtained for the D1c episode.

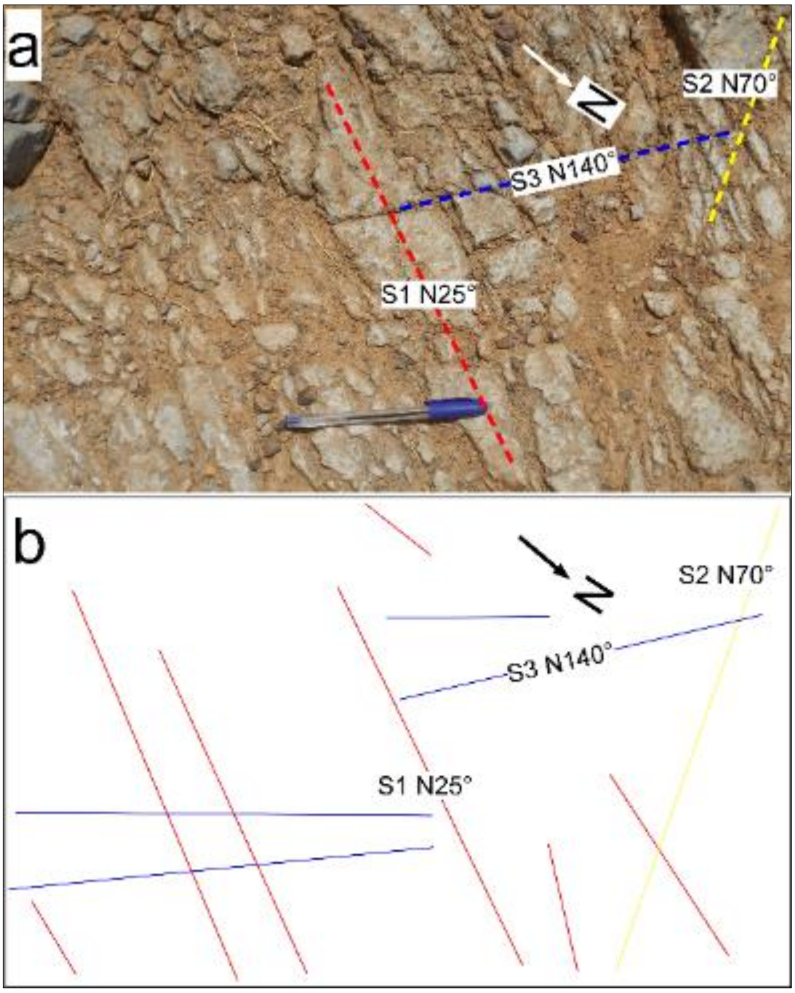

Figure 4 Talcschist affected by three planes of cleavage: S1, S2 and S3

4.2. D2 deformation phase

This is an essentially brittle deformation phase. It is represented by submeridian fractures and conjugate WNW-ESE (sinistral) and ENE-WSW (dextral) thrusts. This strike-slip system is compatible with a generally E-W direction of shortening.

5. Discussion

In the Diagorou-Darbani greenstone belt, structural analysis indicates that there are at least two major deformation phases D1 and D2. The first deformation phase, D1, is characterized by cleavage, micro-folding, boudinage and shear zones. This D1 phase comprises three episodes D1a (ductile to semi-ductile), D1b (semi-ductile) and D1c (semi-ductile to brittle). The second deformation phase D2, is brittle and post-Birimian (Figure 5).

5.1. Eburnean deformation phase D1

5.1.1. Ductile to semi-ductile D1a episode

The D1a deformation episode is characterized by cleavage/foliation (S1). This episode has been linked to an average NW-SE shortening (N130°).

In the Niger Liptako, this D1a episode is comparable to the D1 phases of [24], [25] in the Téra-Ayorou pluton. In the Diagorou-Darbani belt, [11] highlighted a NW-SE regional shortening episode (D1a) similar to the D1a episode in the present study. This D1a episode is similar to the early episodes of the D2 deformation phase obtained by [16]. In the Gorouol belt, this D1a episode is similar to the D1a episode obtained by [22] and to the D1 phase of [43], [44]. This D1a episode is also comparable to the D1a episode obtained by [23] in the Makalondi belt. As shown by [9], [28], the transcurrent episode of deformation (D1a) affecting the Niger Liptako around 2170 Ma could correspond to lateral accretion 'gluing' this domain to an eastern bloc. According to these authors, the D1a compression is also linked to a continuum of deformation and magmatic manifestations suggesting a diachronism of Eburnean deformation. This deformation continuum would be strongly influenced by the emplacement of large granitoid plutons and by the operation of regional shear zones [11], [16]. For [17], [11], the D1a episode is globally linked to the emplacement and swelling of large granitoid plutons.

At the scale of the West African Craton, the D1a episode obtained in the present study corresponds to the early deformation phase (D1) highlighted by [3] in Burkina Faso, which has been attributed to tangential tectonics. This D1a episode is also comparable to the D2 deformation phase described in Burkina Faso by [45] and to the D1 phase described by [46], [47]. In Senegal, this D1a episode is equivalent to the D1 deformation phase of [48]. The D1a episode highlighted by the present study corresponds in Mali to the D1 phase of [49]. This D1a episode coincides respectively with the Eburnean D1 and D2 deformation phases described by [49], [50] in the Siguiri greenstone belt in Guinea. In Ghana, a similar deformation phase (D3) was reported by [7].

5.1.2. Semi-ductile D1b episode

The D1b episode of ductile to semi-ductile deformation is characterized by the crenulation cleavage S2, micro-folding, boudinage and dextral shear channels responsible for the S1/C mills. This semi-ductile episode D1b has been linked to NW-SE shortening

In the Niger Liptako, this D1b episode is comparable to the D2 phase described by [16] and to the D1b episode described by [11] in the Diagorou-Darbani belt. It is also comparable to the D1b episodes described by [22], [23] in the Gorouol and Makalondi belts respectively. This episode is comparable to the D2 of [24] in the Téra-Ayorou pluton.

In the West African Craton, the D1b episode is comparable to the Eburnean D2 deformation phase defined in Burkina Faso, Côte d'Ivoire and Ghana [3], [4], [10], [19], [52]–[54].

5.1.3. Semi-ductile to brittle D1c episode

The semi-ductile to brittle D1c episode is associated with fractures and fracture cleavage S3 N90° to N120° and sinistral shear zones. It affects all the previous formations. This compressive episode is characterized by an NNE-SSW to NE-SE shortening direction.

In the Niger Liptako, this D1c episode is comparable to the D2 obtained by [19] and the D1c episode of [22] in the Gorouol belt. In the Diagorou-Darbani belt, this D1c episode is similar to the D3 of [16] and to the D1c episode obtained and the D2 described by [11]. The D1a episode is similar to the D1c of [23] obtained in the Makalondi belt. At the scale of the West African Craton, this D1c episode is comparable to the D3 revealed in Burkina-Faso [3] and Ivory Coast [54].

5.2. Post-Eburnean deformation phase D2

The D2 deformation phase is characterized by conjugate dextral and sinistral shear fractures. This D2 deformation phase is comparable to the D2 phases of [23], [25] in the Makalondi belt and the Téra-Ayorou pluton respectively.

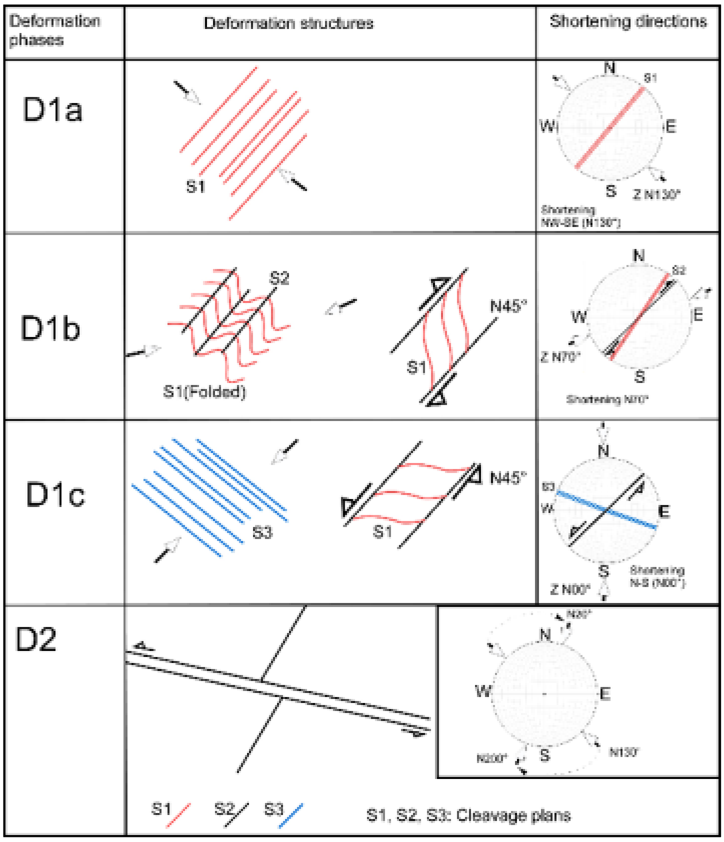

Figure 5 Schematic model of the different deformation phases affecting the formations of the Diagorou-Darbani greenstone belt south of Téra

6. Conclusion

The geological formations of the Diagorou-Darbani greenstone belt in southern Téra are affected by two major deformation phases, D1 and D2.

Phase D1 comprises three episodes: D1a, D1b and D1c. The first episode (D1a) developed the S1 cleavage (NE-SW). This episode is linked to a NW-SE shortening (N130°). The second episode (D1b) is marked by S2 crenulation cleavage, micro-folding and the dextral reactivation of N45° shear zones. This episode is linked to an E-W shortening. The third episode (D1c) is highlighted by the NW-SE S3 fracture cleavage and the sinistral reactivation of the N45° shear zones. A N-S to NNE-SSW shortening was obtained for episode D1c. Phase D2 is essentially brittle. It favored the development of submeridian fractures and conjugate WNW-ESE (sinistral) and ENE-WSW (dextral) shear fractures. This deformation is compatible with a generally E-W direction of shortening.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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